Nanotechnology: Assets and Opportunities for New Jersey

A Report of the
New Jersey Commission on
Science and Technology

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Executive Summary

The emerging fields of nanoscale science, engineering and processing are providing the unforeseen power to understand and control the properties of many natural and human-made products at the atomic and molecular level. Much the way information technology has changed the world in the last several decades, the ability to control matter at the nano level (about 80,000 smaller than the thickness of a human hair) will change most technology based products of the future and significantly impact the global economy.

According to the National Science Foundation, the market in the United States for products and services based on nanotechnology could reach over $1 trillion by 2015. Application of nanotechnology will result in revolutionizing technology-based markets as diverse as pharmaceuticals and medical devices, sensors, power generation, the environment, information technology and data storage. Even tennis balls and cosmetics are being impacted significantly by nanotechnology. Nanotechnology is critical to New Jersey's economic growth and our ability to create new, high paying jobs across much of our industry base.

Federal and state governments and most recently the private sector have made significant investments in nanotechnology because of its potential economic impact. The Federal investment is currently about $1 billion annually and in his 2006 State of the Union Address, President Bush called for doubling the R&D budget in areas like nanotechnology to remain globally competitive. An analysis of 33 large global corporations by Lux Research, a premier global research and advisory firm focusing on the business and economic impact of nanotechnology, estimated that $3.8 billion of corporate R&D went into nanotechnology in 2004.

Global competition among regions for research, talent and high technology industry is occurring. The winners will be those best able to provide R&D funding, state of the art nanotechnology facilities, the ability to scale-up and prototype, commercialization services and support, manufacturing capabilities and the pull though of large corporations who will be relying on less risk adverse entrepreneurial start-ups to develop and demonstrate the technology.

Nanotechnology is a major platform for economic growth in New Jersey and has implications for the state's overall economic competitiveness. New Jersey possesses a strong position in key industries including pharmaceuticals, materials, electronics, telecommunications and energy that will need to integrate nanotechnology into their existing product mix and develop new products based on nanotechnology to remain competitive. New Jersey has significant university assets critical to the advancement of nanotechnology and the entrepreneurial spirit required to translate science into commercial products that meet the needs of society. However, New Jersey will need to invest in our research base and infrastructure and provide capital and commercialization support to emerging businesses to reach our potential.

With targeted and significant investments in infrastructure, programming and entrepreneurs, New Jersey can be a hotspot for nanotechnology. Investment in our universities and emerging technology businesses is critical in order to prepare the work force and create economic growth for New Jersey.

Without a significant investment, New Jersey will fall behind.

Ensuring the Competitiveness of New Jersey Industry

New Jersey is concerned about ensuring quality job growth in the years ahead, particularly in the face of stiff global competition for knowledge-based work. Nanotechnology is an emerging technology that many view as leading the next industrial revolution. Not only will nanotechnology drive the formation of new, growth oriented innovative companies in New Jersey, but the advancement of nanotechnology will be critical to preserving quality jobs in industries in which New Jersey today holds a competitive edge. New Jersey is recognized as an international leader in many key industries where nanotechnology is expected to have a major impact. See Appendix I

In the area of pharmaceuticals, New Jersey is one of only five states with a large and highly specialized presence of drug and pharmaceutical companies according to the Biotechnology Industry Organization. By 2014, Lux Research estimates that pharmaceutical companies in New Jersey and elsewhere are expected to have 23% of their sales revenues derived from incorporating nanotechnology into pharmaceutical products. Sales of nano-based delivery systems for therapeutics will lead those sales. In electronics, the American Electronics Association (AeA) notes that New Jersey is 3rd in the nation in defense electronics. Nanotechnology is projected to revolutionize electronics, accounting for 75% of sales revenue by 2014 according to Lux Research. Advances in logic chips patterned on nanolithography, memory chips based on nanomaterials and nanostructured chip cooling systems will be among those innovations and consistent with areas of expertise at Princeton, Rutgers and NJIT.

Building on New Jersey's Focus in Nanotechnology

New Jersey has a solid standing in nanotechnology activities, with 388 patent and federal R&D grants to universities and industry from 1995 to 2005. This places **New Jersey 6th in the nation in patent awards, 12th in NSF awards, and 19th in NIH awards compared to other states.**

Most near term (1-5 years) applications of nanotechnology will build on nanomaterials where New Jersey based industry and universities are recognized *globally* as 'stars' in the field. These short-term material based opportunities can result in a range of commercial applications from stronger and lighter materials for automotive and aerospace applications to antibacterial nano-particles in wound dressings and more efficient nano-catalysts for use in energy generation.

An analysis of patent and federal R&D awards in nanotechnology by Battelle for the Mid-Atlantic Nanotechnology Alliance, a Federally funded initiative of New Jersey, Pennsylvania, and Delaware, found that in New Jersey:

- **34% of the State's nanotechnology activities are in nanomaterials,** particularly in high temperature materials, nanoporous materials and carbon nanotubes. Across the Mid-Atlantic region, New Jersey's strength in nanomaterials is reflected in 60% of the patent and federal R&D awards in the broad category of nanomaterials. Among the leaders in nanomaterials in New Jersey are Honeywell International and ExxonMobil.

- **16% of New Jersey's awards in nanotechnology are found in nanocomposites** that are made from the mixing of two or more materials to result in unique properties. For example, the distribution of a small amount of nanoparticles in some materials can significantly change electrical properties of that material while a nanocoating on a solid surface can impart resistance to ultraviolet rays or oxygen permeation. Among the leading institutions in this area are Rutgers and NEI Corporation.

In the next 5 to 15 years, it is expected that nanotechnology will be critical in the development of nanodevices and nanoelectronics for medical treatments, diagnostics, faster computers and advanced sensors.

- **27% of the state's nanotechnology activities are found in the emerging area of nanoelectronics,** particularly optoelectronics and thin films. The emerging nature of this field is reflected by the institutions leading this area, Rutgers University and Princeton University.

- **14% of the state's nanotechnology activities are found in the emerging area of nanobio** applications, lead by biological sensors, drug targeting and DNA-related tools. Rutgers and Princeton lead the state in this area.

- **9% of the state's nanotechnology activities are found in the enabling areas of nanofabrication, nanotools, and manufacturing** technology in general led by NJIT, Rutgers University and Princeton University.

The expertise in our universities and colleges align extremely well with Federal nanotechnology funding priorities. Our global reputation for excellence in material science and basic research and our proficiency in engineering and manufacturing technologies increase the opportunity for our researchers and emerging technology businesses to successfully compete for Federal grants. New Jersey, however, has not made significant investments in its universities over the last ten to fifteen years. As a result, our dominance in some areas of research is in jeopardy. The availability of matching state funds can increase the likelihood of obtaining Federal funds.

In the 2006 Federal nanotechnology budget outlined below, over $750 million is available in grants in technology areas directly related to research currently taking place in New Jersey universities. Additionally, close to $150 million is budgeted for nanotechnology research facilities and equipment acquisitions sorely needed in New Jersey.

1. Fundamental Nanoscale Phenomena and Processes ($234 million)
2. Nanomaterials ($228 million)
3. Nanoscale Devices and Systems ($244 million)
4. Instrumentation Research, Metrology, and Standards for Nanotechnology ($71 million)
5. Nanomanufacturing ($47 million)
6. Major Research Facilities and Instrumentation Acquisitions ($148 million)
7. Societal Dimensions ($82 million)

New Jersey's Assets in Nanotechnology

New Jersey holds a leading national position in key industries like pharmaceuticals, medical devices, chemicals and materials, telecommunications and information technology which will ultimately pull-through the technology developed in our universities and emerging businesses to create high paying technology based jobs.

New Jersey has a robust base of companies actively engaged in nanotechnology R&D, with more than 50 New Jersey companies generating patents and receiving federal R&D awards in nanotechnology. Some of the New Jersey companies currently engaged in nanotechnology include Honeywell, ExxonMobil, Lucent, Engelhard, Sarnoff, Orthodiagnostics, Salvona Inc., Inmat, NanoOpto Corp., NEI Corp., Nanopac Technologies, Nanonex, Nanomedica, UHV Technologies, Tech Elan, Kulite Semiconductor, Parelec and others.

New Jersey has world-class universities engaged in interdisciplinary nanotechnology research with over 150 faculty, 125 post doctoral fellows and close to 400 graduate students

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Universities	Nanotechnology Focus Areas Identified From Interviews and Review of Grant Awards																
	Materials Synthesis and Characterization						Nanoelectronics					Nano-bio			Energy Applications		
	Advanced Characterization (non-commercial)	Ceramic-based nanomaterials and nanocomposites	Carbon nanotubes	Nano-coatings	Nano-composites (non-ceramic)	Polymers and Synthetic Proteins	Electronic materials/ Thin Films	Nano- Lithography	Nano- Magnetics	Nano- Electro-mechanical systems	Nano- optoelectronics	Biomaterials , Tissue Engineering and Regenerative Medicine	Bio-imaging & sensing	Drug discovery, development and delivery	Catalysis & Fuel Cells	Energy Storage	Solar Cells
NJ Institute of Technology	X		X			X	X				X		X	X	X		X
Princeton	X					X	X	X	X		X		X				
Rowan								X	X								
Rutgers		X		X	X		X		X		X	X		X		X	
Stevens Institute			X		X	X	X						X				

- **Princeton** is the sole New Jersey University awarded a very prestigious Federal Nano Research Center Grant. They have more than 24 faculty, 50 graduate students and a dozen post docs involved in nanotechnology research.

  Their nanotechnology efforts span a number of centers and academic departments including PRISM (Princeton Institute for the Science and Technology of Materials), PCCM (Princeton Center for Complex Materials), NSF-MRSEC (a National Science Foundation funded Materials Research Science Education Center), and in individual departments such as Electrical Engineering, Chemistry, Physics, Mechanical and Aerospace Engineering, Chemical Engineering, and Geology, as well as the Plasma Physics Lab. Areas of concentrations and specialized/unique expertise in nanotechnology include: bio/nano interface, nanofabrication/nanoprocessing, nanostructured materials/nanotextures, nano and qc devices, nano organic and nano photonic systems, nanofluidics, self assembly, nano theory and modeling, nanoimaging and analysis, and nano infrastructure for research and prototype development and industrial collaboration.

  Princeton has three major multi-user facilities for nano/micro processing and fabrication, imaging and analysis, and theory and modeling computations, representing more than $30 million in specialized equipment. New additions to the Nanoprocessing Suite will include a Laser Writer, Nanoimprinter, and High Res E-Beam writer. The multi-user facilities operate in support of over 200 academic, industry and government lab collaborators including Exxon, Rhodia, Sarnoff, Nanonex, NanoOpto, BioNanoMatrix, Sunstones, and Vincogen.

  In addition to its extensive nanotechnology facilities, Princeton brings a strong research focus in:

  - **Thin film electronics and nano over large areas**, including the scaling of electronic devices to nanoscale, growth of novel materials on near-atomic scale, materials processing, and application in electronic devices, electrical properties of thin films and microstructures of semiconductors and solid-state physics.
  - **Nano-imprint lithography** involving applications in nano-electronics, nano-magnetics, nano-optoelectronics, semiconductors and polymers.
  - **Microfluidics and other nano-related aspects of condensed matter** including miniaturized automated systems for fluidic handling, flow and stability of micro and nanostructures in liquid phase, transport phenomena on free surface thin-film structures, energy flow in biomolecules, applications of microlithography to biology and general properties of complex quantum systems.
  - **Ultrafast lasers** including development of laser spectroscopy, atomic beam surface diffraction and reflectivity, synchrotron x-ray surface diffraction and reflectivity, and scanning probe microscopy (STM and AFM).

- **Rutgers** has approximately 100 faculty, ~300 graduate students and ~100 post docs involved in nanotechnology research from eight different academic departments Their areas of focus are along three main areas, Energy and Engineering (mostly chemical); Electronics and Sensors (assorted devices, including opto and telecom); and Bio (bio-nano, bio-Pharma, bio-materials). They have ~$35 million in nano funding which includes a recent notification that they will receive an Engineering

Research Center (ERC) grant of approximately $20 million in the area of Structured Organic Composites. Four technology transfer laboratories are being planned as testing grounds for new technologies to manufacture pharmaceutical materials and bio-nano products. Rutgers plans to use the facilities to bring together pharmaceutical manufacturers, equipment manufacturers, instrument suppliers and computational modeling and control specialists. Rutgers faculty will provide the research needed to integrate the various components into manufacturing platforms. The facilities will be open to large and small companies and other university researchers.

The plan consists of the following proposed laboratories:

1. Continuous Organic Macrocomposite Manufacturing
2. Organic Nanoparticle Synthesis and Processing
3. Hierarchical Synthesis of Organic Microcomposites
4. Pharmaceutical Mini-Micro Manufacturing

Rutgers currently has about $50 million invested in equipment applicable to nano research within their academic departments and centers. There have been several faculty spin-outs to date. There has been significant external collaboration with Picatinny, Lucent, and Ft Monmouth; Princeton, NJIT, Stevens, Rowan, and other universities; Federal Labs; and small companies like Polymerix and Semorex. Rutgers has 12-15 courses per year that are predominantly modern Nano oriented in Chemistry, Physics, Materials Science, etc.

Current focus areas in nanotechnology that stand out at Rutgers, include:

- **Synthesis of unique nanostructures**, including establishing structure/properties/processing relationships in nanophase coatings and bulk materials, synthesis and processing of nanophase materials, nanostructured ceramics and polymers, and thin films.
- **Interfacial science for nanoelectronics** involving basic studies of surface, ultrathin films, and interface systems for next generation transistors, high-K dielectrics, optoelectronics and molecular electronics, studies include interfaces of technologically important electronic, photonic, organic and biological heterostructures.
- **Biomaterials** involving the synthesis and characterization of biocompatible polymers for medical and dental applications, cellular bioengineering, analysis and control of cell-biomaterial interactions, applications to immune cell engineering, biomimetic materials interfaces to control cell functions, and functional induction of epithelial tissues.
- **Energy applications**, particularly energy storage chemistries enabled by advances in materials science.
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- **Quantum, condensed matter and organic electronics** involving theoretical studies, such as strongly interacting electron systems, and novel magnetic states in strongly frustrated materials, theory of spin glasses, physics of quantum computation, and flux states in disordered superconductors.
- **Simulation modeling** involving molecular dynamics simulations, surface science diffusion in glasses, thin films and coatings.

- **The New Jersey Institute of Technology** has approximately two dozen faculty, 12 graduate students and 6 post docs involved in nanotechnology research from six different academic departments (Electrical, Biomedical, Mechanical, and Chemical Engineering, Chemistry and Physics Departments) working collaboratively on nanotechnology with researchers from federal, corporate and military laboratories. Their areas of focus include carbon nano tubes, nano particulates, semiconductor wires, fuel cells, nano-magnetism, nano-bio, coatings, nanopharamceuticals and nanoenergetic materials.

  NJIT has over $10 million in nano funding and has developed interdisciplinary nanotechnology courses and holds regular seminars and nano meetings. External collaborators include Lucent, Mt. Sinai Hospital, Honeywell, Intel, Picatinny Arsenal and others.

  Focus areas of nanotechnology activity include:
  - **Advance Characterization** applying a range of approaches including raman spectroscopy, infrared screens, and ultra-violet characterization.
  - **Nanomaterials synthesis** ranging from self-assembled silica and semiconductor nano-films to polymers and synthetic proteins to controlled fabrication of carbon nanotubes and wires to nano coatings for corrosion protection films to nano composites made of carbon nanotubes and organic semiconductors. Functionalization of carbon nanotubes by unique microwave processing technology and subsequent integration into complex structures and devices.
  - **Nanoparticulate process technology** with applications ranging from advanced energetics to next generation pharmaceuticals. Emphasis on novel coating processes for controlled production at nano-scale.
  - **Nanoelectronics** involving a range of activities from electronic materials to nano-optoelectronics using carbon nanotubes to nano-semi-conductors. Includes wide area electronics using nano structured materials
  - **Bio-nano**, involving efforts in biomaterials (stem cell differentiation research, bio-synthetics processing), bioimaging and sensing, and drug delivery.
  - **Energy** applications in catalysis and fuel cells (including bio-fuel cells) and solar cells.
  - **Manufacturing, scale up technologies, prototyping** expertise which can ultimately be a foundation for rapid prototyping at the nano level.

- **Stevens Institute of Technology** has 25 faculty, 22 graduate students and 8 post docs involved in nanotechnology research from five different academic departments (Chemical, Biomedical & Materials Engineering; Chemistry & Chemical Biology; Physics & Engineering Physics; Civil, Environmental & Ocean Engineering; Mechanical Engineering). Several research centers also participate in nanotechnology including the NJ Center for Micro-Chemical Systems, the Highly Filled Materials Institute, the Design and Manufacturing Institute and the Center for Environmental Systems.

Stevens has $9 million in Federal grants, NJ DEP nano funding and significant investment from the US Army ARDEC for dual use applications. Several laboratories at Stevens support the nanotechnology research for dual use applications including MicroChemical Lab, MicroDevice Lab, MicroParticle Characterization Lab and Nano Imaging facility. Stevens has developed an interdisciplinary nanotechnology graduate program that spans 5 different academic departments. The program will soon be open to industry participants. External collaborators include Lucent, Cornell, MIT, US Army ARDEC, BMS, FMC, Sarnoff, UMDNJ, mPHASE, etc.

Key focus areas funded at Stevens by the National Science Foundation include:

- **Nanoscale processes** in chem/bio-microreactors.
- **Nanocomposites** involving nanoparticle and structural synthesis, particularly in the use of nanoscale inclusions and surface-mediated assembly of polymers.
- **Nanomaterials** involving carbon nanotubes and high temperature applications.
- **MEMS/NEMS devices** for active structures, RF switches and nano-manipulators.
- **Nanobio** involved in sensor applications drawing on nanoelectronic and nanomaterials expertise.
- **Environmental nanotechnology** for pollutant treatment.
- **Environmental fate, transport and toxicological** impact of organic and inorganic nanoparticles.

- **Rowan** has approximately 8 faculty and 5 graduate students involved in nanotechnology research from five different academic departments (Chemical Engineering, Chemistry, Electrical & Computer Engineering, Mechanical Engineering, Physics) working collaboratively on nanotechnology with researchers from Columbia University, Drexel University, University of Maryland – College Park, Washington University in St. Louis, India Institute of Technology in Delhi, and India Institute of Technology in New Delhi.

  Rowan has grants of more than $2.0 million through collaborations with the NSF Nanoscale Science & Engineering Center with Columbia; NSF Nanoscale Interdisciplinary Research Team with Columbia; NSF Focused Research Group with Drexel; and Materials Science & Engineering Center with University of Maryland. Their nano related equipment includes a SEM with e-beam writer – 20 nm resolution; JEOL variable temperature atomic force microscope with scanning tunneling microscope; and nano-indenter External collaborators Three-One-Two, local start up. They have developed a curriculum in Nanoelectronics.

  Focused areas of activity in nanotechnology include:

  - **Nano-lithography** involving nano stamping, patterned magnetic media, and masks for nanoimprint lithography.

- **Nano-magnetics** including electric transport magnetization, microwave resonance, magnetic ordering on electronic properties and scanning property mapping techniques.
- **Nanomaterials** ranging from organic synthesis, synthesis of new materials by traditional and low-temperature methods molecular modeling and novel applications of high-performance polymers.

Picatinny Arsenal's radiofrequency plasma reactor, the largest and first of its kind in North America can produce a wide range of nano particles in sufficient quality and quantity to meet the product development and market assessment needs of commercial partners. A very significant Federal investment went into this dual use facility (military and commercial uses). It has a highly trained staff, characterization equipment and office space available for use by collaborators through the duration of joint projects. They plan to add equipment to ultimately be able to produce parts from nanocomposites.

Lucent, is the home of the New Jersey Nanotechnology Consortium (NJNC) which provides rapid and cost-effective access to nanotechnology research and development services to university researchers. The nucleus of the NJNC is the world-renowned Bell Labs nanofabrication laboratory in Murray Hill, along with the 1000 Bell Labs scientists and researchers who are available to support the research of small nanobased businesses and university faculty. By combining fabrication capabilities of this lab with regional academic research institutions and universities, NJNC is able to carry out basic and applied nanotechnology research and help bring nanotechnology ideas from concept to commercialization.

The Lucent facility is a 20,000 square foot, $400 million fully depreciated asset which employs 30 full and part time highly skilled staff. The ability for researchers using the facility to draw on the 1000 Bell Lab scientists at the site in Murray Hill is as important to their success as the facility itself. At this time, the impact of Lucent's merger with Alcatel on future access of New Jersey researchers to the nanofacility is unknown.

The Mid Atlantic Nano Association (MANA) was formed in the Fall of 2004 as a unique tri-state, Federally funded initiative of New Jersey, Pennsylvania, and Delaware. MANA is focused on developing on-the-ground strategic alliances of industry and universities that can effectively position the tri-state region for leadership in nanotechnology which will attract additional investment.

> The founding members of MANA – the New Jersey Commission on Science and Technology, the Ben Franklin Technology Partners of Southeastern Pennsylvania and the Delaware Technology Park – were successful in securing $300,000 start-up matching funds from the U.S. Department of Commerce Economic Development Administration to create the nation's first multi-state nanotechnology initiative. Battelle's Technology Partnership Practice, a leading technology-based economic development consulting firm, was hired to assist the MANA partners.
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> The strategic MANA project is focused on having an ***impact*** on the region's nanotechnology development. The goal is to be able to identify opportunities for strategic alliances in nanotechnology based on competitive analysis, market potential and leveraging of the region's assets to accelerate commercialization and bring more

Federal nanotechnology research funding into New Jersey and the region. The region leads the nation in a number of areas:

The MANA region (New Jersey, Pennsylvania, and Delaware) ranks high in its ability to attract Federal nanotechnology grants demonstrating significant innovation, research and commercial strength across the region. As the nation's first tri-state collaboration in nanotechnology, the region can have a significant competitive advantage attracting Federal nanotechnology funding since increased collaboration across disciplines and institutions is a key goal of the Federal Nanotechnology Initiative.

When the accomplishments for each of the states in the tri-state region are consolidated, the region has done very well attracting Federal funding. Strategic collaborations in the future will improve on the current results:

- **Second** nationwide in nano-related patents
- **Third** in National Science Foundation (NSF) nano-related grants
- **Fourth** in National Institute of Health (NIH) nano-related grants

Nano focused networking groups like the Greater Garden State Nano Alliance and SMART are bringing together researchers, legislators and large and small companies for discussions on nanotechnology research and market needs.

Short & Long Term Opportunities For New Jersey In Nanotechnology

Areas of potential opportunity for New Jersey to grow jobs in nanotechnology are based on the State's assets, expertise, competitive advantage and potential for commercialization. Both short term and long term opportunities for job growth exist, especially those that build on New Jersey's strengths in materials research and manufacturing.

New Jersey universities are recognized *globally* as 'stars' in the field of materials research which is the foundation of nanotechnology in everything from catalysts, composites & coatings for large, near term (~5 year) markets like automotive, recreation, etc. to longer term markets (10+ years) in energy, nano drug development and delivery and bio materials. Combining the material science strengths of our universities with the market pull through provided by New Jersey based materials giants like BASF, Honeywell and Engelhard and the pharmaceutical drive of companies like J&J, Merck, Schering Plough, etc. provides a robust infrastructure and potential supply chain in nano based materials.

Building on New Jersey's global reputation in Advanced Materials and Manufacturing, major opportunities for the state's investment focus include:

Nano Prototyping and Manufacturing: The need to address the challenges of nanotechnology scale-up and manufacturing is critical to realizing the trillion dollar opportunity in nanotechnology. New Jersey has considerable strengths in this arena; there is little competition from other universities and significant potential for Federal funding since this is a key NSF focus area for the nation. The translation of discovery to commercialization, often referred to as the "valley of death", includes the need for rapid prototyping, scale-up and proof of concept.

Given the strength in nanomaterials found within the industrial sector in New Jersey, it is critical that there be a mechanism to move up the nano value chain and translate these nanomaterials into nano-enabled devices and products where the major economic gains from nanotechnology will be realized. Investment in nano-prototyping and manufacturing could result in New Jersey becoming a leader in the precision and customized manufacturing processes involved in nanomanufacturing and it could contribute to retention of 21st century manufacturing jobs, now lost to off shoring.

New Jersey possesses significant facilities to realize this nano-prototyping and manufacturing focus. The universities in New Jersey have in place existing facilities for nano-scale synthesis, characterization and small-scale fabrication and processing, which provide a strong foundation for future investments. New Jersey also has specialized nano-related scale up facilities with the presence of Picatinny's RF Plasma Reactor and the Lucent wafer facility.

The direction of rapid prototyping must be driven by market demand and be specific to application areas. No one multi-user prototyping or manufacturing facility will meet the very different needs of the Bio-Pharma nano sector and those of optoelectronics, catalysis, energy, etc.

Bio-Nano: New Jersey has a significant advantage not only because the heart of the pharmaceutical industry is located here but also because of our university research capacity in bio-materials and bio-pharma. Opportunities span novel nano-based drug delivery devices including sustained or rapid release technologies and drug development with target specificity. Implants made of nano composite materials which offer superior

mechanical properties or tailored surface chemistry to reduce rejection or release drugs are major long term opportunities.

Nano-based personal care products are currently the largest commercial applications of nanotechnology. Nano materials are being used in cosmetics and sunscreens along with anti-aging and moisturizing lotions which are very effectively absorbed through the skin. This market is expected to grow significantly with the aging of baby boomers and increased concern over UV damage to the skin.

Other short-term (5 years) commercialization opportunities will most likely be novel and more effective delivery of drugs currently on the market through nano-based devices and implants. New to the world nano-drugs will have much longer lead times to commercialization. Engaging large pharma and medical device companies will be challenging because of the large investments required to commercialize new technologies and the risks involved. Researchers and emerging small businesses will need to demonstrate their technology through prototypes and provide animal and human data to demonstrate viability and safety before attracting many pharma companies to nano-based solutions.

The key advantage for New Jersey in bio-nano is its established based of pharmaceutical and medical device companies. Tailoring unique scale-up, testing and demonstration facilities may offer New Jersey a way to ensure that future nano-bio activities can be rooted within the state and linked with clinical research activities underway at UMDNJ. While New Jersey has active research programs in bio-materials and nano-based drug delivery led by Rutgers, there is a significant need to ramp-up university strengths in this area to make the significant promise of bio-nano. Partnering with both Pennsylvania and New York will enhance opportunities to conduct clinical trials.

Electronics and Photonics: Opportunities for displays, sensors and networks, MEMS/NEMS, data storage and memory are significant, potential long-term nanotechnology opportunities for New Jersey. Nano-electronics is an area where New Jersey universities bring broad strengths and opportunities. All of the universities, from the major research universities of Princeton and Rutgers, to the more focused research efforts at NJIT, Stevens Institute and Rowan, have active programs.

However, many current opportunities are tied to Telecom so near-term markets are limited. In the long term, New Jersey can maintain its traditional strengths and position itself for the next wave of commercial opportunities through investment. Princeton, working closely with Sarnoff, Lucent and other emerging nano-based New Jersey companies and universities can be at the lead of the next generation of technology which some envision as the replacement of electronics with optical technologies.

Clean Energy and the Environment including Catalysts: Major market potential in the near and long term includes catalysts, absorbents, batteries, fuel and solar cells, etc. Engelhard and BASF are leaders in nano-based catalysts for energy conversion and New Jersey has a rich university base in materials upon which to build. Opportunities also exist for collaboration with MANA partners, especially the University of Delaware which has one of the nation's largest centers for energy related research and catalysis.

With the escalating price of oil now routinely above $60 a barrel, the economic feasibility of alternative/clean energy sources rises as a clear market opportunity. Clean energy

technologies – including solar power, fuel cells, microturbines and wind power – accounted for less than $7 billion in 2000 and are forecasted to grow at more than 30% annually, reaching over $80 billion by 2010. What we can expect in the future is not one substitute for oil and natural gas, but a diversified energy future, with many technologies helping to meet our needs including those based on nanotechnology.

In the area of alternative clean energy, New Jersey's strength is found more in its industry sector than in its university sector. At the industry level, New Jersey has a long history in petro-chemicals and many potential industry partners exist such as Degussa Metals Catalysts, Johnson-Matthey Fuel Cells, Headwaters NanoKinetix, Hydrocarbon Technologies (coal liquefaction), Philips Lighting and Nano-Engineered Innovation. At the university level, New Jersey is not a leader in fuel cell or solar power research, though focused programs exist such as the energy storage center at Rutgers and several research teams across the state are working on solar power and fuel cells. This is an area where New Jersey can make investments to help grow into an emerging market in collaboration with industry and its MANA partners.

Funding Opportunities for New Jersey in Nanotechnology

For New Jersey to achieve its potential in nanotechnology and grow our economic base, a significant State investment in the near term will be required.

Funds are needed to provide university researchers and small and medium sized businesses with facilities, equipment and grant support to invent, develop and commercialize nano-based technologies. In addition to physical facilities and equipment, investment needs to be made in student training and development of an infrastructure to enhance collaboration among researchers and corporations. Public and private funding that provides commercialization support will also be required. The areas in most need of investment are as follows:

1)Nanotechnology Multi-User Center(s) of Excellence: a collaborative, inter-university infrastructure for nano research, development and commercialization targeted to the interests of New Jersey based industry partners and in alignment with national priorities and Federal funding. The goals of the Center(s) go beyond basic research to economic development and job creation in New Jersey.

Funds are needed for new construction and/or renovation of existing space (clean room, laboratories, office and public space) at one or more university locations through a competitive proposal process. No one nanotechnology facility will be able to support the range of opportunities for New Jersey described above. A 'generic' facility will offer little advantage to Federal funding agencies and corporate partners. The goal is to create state-of-the art, fully equipped multi-user nanotechnology facilities which build on university research strengths and bring value to New Jersey businesses as demonstrated by corporate investment and collaborative research.

2) A State nano equipment fund The equipment needed to support nanotechnology research in New Jersey universities and colleges will be costly, will include clean rooms, and will vary significantly based on the focus of the research. Although a laboratory researching biomaterials for improved artery stents and one developing improved composite materials for aerospace applications may share some characterization equipment, each research area will require specialized equipment that could also be available for use by emerging businesses and corporate researchers.

3) Faculty and Students: Attracting star faculty to New Jersey's universities will require sufficient funds for research, graduate students and postdoctoral positions. High profile faculty experts can draw significant corporate and Federal funding to their institutions.

4) Emerging Business Support: Angel support and venture capital is less available to New Jersey based emerging businesses than those located in other states such as California and Massachusetts. To keep the best and brightest in New Jersey, the State should provide some portion of the support that would be provided by a stronger in-state venture community.

Examples of possible State support:

- **Commercialization grants,** Commercialization grant support at the end of an SBIR Phase 2, for scale up, prototyping, assistance with clinical trials, etc.

- **IP Fund,** a legal expense fund for nano patent applications and licensing university IP

- **Subsidized Incubator rent** and operational support for start-up companies developing nanotechnology based products

- **Business Fellowship support** to include apprentice positions for graduating MBAs to work in nano-based companies for one to 2 years to assist in commercialization

- **State-Wide Business Development/Mentoring Group,** an assemblage of former corporate executives, VCs, Wall Street market segment analysts, etc. who have networks into various corporations/market segments in NJ (Pharma, telelcom, etc.) and are committed to providing guidance and commercialization support to some of the State's top emerging nano-based technology businesses as referred through NJCST, EDA, etc.

5) **Matching Funds for Nanotechnology Research and Development at Universities and Emerging Businesses,** a guarantee of matching state funds *significantly* improves chances for 3rd party funding and can increase Federal grants in New Jersey.

6) **Industrial Support/Angel guarantees**, key State related entities involved in Technology Based Economic Growth in New Jersey such as the Office of Economic Growth, the New Jersey Commission on Science and Technology, the Economic Development Authority, the Commerce Commission, the Department of Labor, etc. to work together to develop a portfolio of economic vehicles to incentivize investors in New Jersey companies which are commercializing nanotechnology.

   For example:

   - Tax credits for investors in nanotechnology-based businesses

   - An enhancement of Techniuum's angel investment guarantee for nanotechnology

   - Increased Net Operating Loss lifetime totals for nano businesses to $10 million

   - A state match at some predetermined level for eligible corporate investments in university research in nanotechnology

   - A relaxation in intellectual property licensing fees for nanotechnology developed within New Jersey universities but licensed to New Jersey businesses

   - A new BEIP program for nano businesses (defined by having client contracts of a predetermined minimum revenue) that delays the need to pay payroll taxes (or places the tax revenues in a general nanofund to be used for low cost equipment loans, etc.) until a specific employee or revenue milestone is met.

- Aggressive support of immigration reform to encourage some of the best and the brightest US educated immigrant nano scientists and engineers to remain in New Jersey.

Competitive State Investments in Nanotechnology

Funding to support research, technology development, prototyping and commercialization is essential to reach New Jersey's potential in nanotechnology. Several other states have invested very significant funds to encourage nanotechnology economic development, particularly New York.

New York State is the national leader in the development of a state-wide nanotechnology infrastructure to encourage economic development and increase high tech jobs. They have invested well over $700 million during the last 5 years and received Federal funding to create a nanotechnology center at the University of Albany. The center, a research and development partnership between the University of Albany and corporations is a model of university, state and Federal government, and corporate collaboration. IBM and other New York based business along with several out-of-state corporations have provided matching investments estimated to be well over a billion dollars. Honeywell has invested $5 million in Albany. Corporate researchers will share the space with faculty. New York is using the Center to lure other nano manufacturers to the region and has set its eyes on a semiconductor manufacturer.

This facility is largely an industry driven asset with IBM bringing major partners such as Samsung, Hitachi and others into the center. The partners in turn are now bringing in their suppliers to build a supply chain cluster.

Arizona and California have each invested about $100 million in nanotechnology centers, research and business support. The **California** Nanosystems Institute is a research center run jointly by UCLA and UC Santa Barbara. It was established in 2000 with $100 million from the State of California and an additional $250 million in federal research grants and industry funding. Its mission is to encourage university collaboration with industry and enable the rapid commercialization of discoveries in nanosystems. **Arizona** raised $400 million through a voter initiative in 2000 that created a 0.6% sales tax increase for education. Nanotechnology, biotechnology, information technology, and manufacturing science will each receive $100 million. The 20-year initiative is estimated to provide $1 billion for infrastructure enhancement at three state universities in support of new economy jobs.

Our MANA partners, Pennsylvania and Delaware have had little state investment to date. Ben Franklin Technology Partners of Southeastern **Pennsylvania** has established the Nanotechnology Institute with Drexel University and the University of Pennsylvania which has a focus on life science. Its mission is to focus on the transfer and commercialization of nanotechnology discoveries and knowledge to stimulate economic growth through support of multi-institutional/inter-disciplinary research & development, industry focused R&D, entrepreneurial business development & commercialization, risk capital, workforce development, economic research, and community of interest networks. $10.5 million in state funding was approved in September 2000 and recently the Governor announced a desire to invest significantly in high technology leading to economic growth, including nanotechnology. **Delaware** has had no significant state investment in nanotechnology but the University of Delaware is seen as a center of excellence in nano based fuel cell technology.

A summary of What Other States Have Invested, additional information in Appendix IV

- **Arizona--** Arizona State University has directed approximately $100 million to nanotech activity
- **California**-- State provided $100 million for the California Nanosystems Institute
- **Georgia**-- Georgia Tech has requested $38 million for a nanotech research center
- **Illinois**-- State provided $36 million for construction of a building for the Center for Nanoscale Materials
- **Maryland**-- Governor's proposal for $2.5 million in operating funds for a University of Maryland nanotech research initiative
- **Massachusetts**-- State provided $5 million to the University of Massachusetts Lowell nanotech manufacturing center
- **New York** --The state has invested approximately $740 million over the past five years and has been able to leverage approximately $2.7 billion from industry partners and another $146 million from federal sources to support programs in Nanotechnology. A new $435 million Institute for Nanoelectronics Discovery and Exploration (INDEX) -- one of only two to be created in the nation**,** will be located at the Center of Excellence in Nanoelectronics at the University at Albany. The center has attracted International Sematech - a consortium of the 12 major computer chip manufacturers**,** to enter into a State and Industry partnership and invest $400 million over the next five years.
- **Ohio-**- State has provided $22.5 million for a Wright Center of Innovation focused on nanotechnology, $4 million for a Biomedical Research and Tech Transfer Partnership award, and $5.3 million for three Wright Projects
- **Oregon**-- State has provided at least $21 million to the Oregon Nanoscience and Microtechnologies Institute
- **Pennsylvania**-- State provided $10.5 million for the Nanotechnology Institute

Appendix I

The Impact of Nanotechnology On Current Markets[1]

Selected Product Categories	MANA Regional Position Today	2014 Sales Revenues Incorporating Nanotechnology	Expected Developments
Specialty Chemicals, Materials, & Coatings	Significant Employment Strong Regional Specification	14%	Key gains in sales expected over 20005-2009 period, led by advances in coatings. Existing companies (directly or through partnerships) will dominate wide scale introduction of nano-materials into marketplace.
Pharmaceuticals	Significant Employment Significant Regional Specialization	23%	Advance delivery of therapeutics with major impact in 2010-2014 period. Similar to biotech, Pharma outsourcing nano-research to universities and emerging companies.
Industrial Machinery	Significant Employment Not Regionally Concentrated	8%	Advanced nano-processing and other nano-tools are key areas for advancing new nanotech company formation. Nanotech tools market could exceed $2.7 B by 2014.
Industrial Electronics & Instruments	Very Large Employment Not Regionally Concentrated	75%	Logic chips patterned on nanolithography techniques, memory chips based on nanomaterials, nanostructured chip cooling systems, nanocomposite RF/EMI shielding. Key opportunity for nano-intermediates to arise in 2010-2014 period.
Paper Products Manufacturing	Very Large Employment Regionally Specialization	5%	Limited nanotech opportunity for conventional paper products – niche anti-reflective coatings and nano-particals enhanced bonding agents. Opportunity lies in creating new paper products such as papers coated with nanoscale polyelectrolytes for integrated sensor and printable electronics applications.
Medical Instruments & Equipment	Very Large Employment Regional Specialization	30%	Wide variety of nanocomposite materials, nanocoatings, nanosensors used in orthopedics, implants, and invasive instrument applications. Nanoparticle uses for enhanced imaging capabilities.
Consumer Electronics	Very Large Employment Regional Concentration	75%	Similar to Industrial Electronics & Instruments.
Automotive	Large Employment Not Regionally Concentrated	21%	Nanocomposites/nanocoatings already used today on specific vehicles. Will be applied across product lines as prices decline with volume. Assessment does not include use of carbon black in tires or impact on vehicle electronics.
Computers	Large Employment Not Regionally Concentrated	37%	New nanolithography techniques will be required to sustain the semiconductor historical price/performance curves. All leading edge integrated circuits introduced from 2007 onward will be patterned with these techniques. The products they power will thus be considered nano-enabled products downstream in the value chain.
Other Land Based Transportation Equipment (e.g., military vehicles, rail cars)	Large Employment Significant Regional Concentration	25%	Nanocoatings, polymer fuel cell components, high temperature superconducting wires for motors, nano-particulate fuel additives, and nanosensors. Non-cost sensitive markets will find other uses in highly valued structural and surface applications
Battery and Fuel Cells	Significant Regional Specialization	33%	All PEM fuel cells represent nanotech applications due to the use of nanostructured catalyst materials. Batteries will eventually be impacted by super capacitor alternatives using nano-structured materials. Solar/photovoltaic cells will see nanotech enabled products coming to market in 2006.

[1] Information Supplied by Lux Research

Appendix II

What is Nanotechnology?

Nanotechnology is the science of creating and building with materials about the size of a nanometer – a human hair is 80,000 nanometers wide. Nanotech can be applied to a wide range of uses – from helping tennis balls keep their bounce to keeping soldiers safe from biohazards.

Today there are a growing number of commercial applications based on nanotechnology which include cosmetics and sunscreens, non reflective eyeglass coatings, catalysts which increase energy output from fuels and composite materials used in automotive bumpers. However, recent progress in the measurement, modeling and ability to manipulate matter at the molecular level, atom by atom, to create large structures with fundamentally new properties and functions will be revolutionary and change not only our most technology based industries but humankind's fundamental understanding of matter.

The Commercialization Model

It is expected that the introduction of nanotechnology into the marketplace will most likely first involve a mix of the existing product lines of major corporations and the development of start-up companies, often in focused niches, offering innovative tools and furthering research and development for specific new product advances.

Second, the demands of success in many important fields have changed. Scientific excellence in emerging fields like nanotechnology demand interdisciplinary collaboration and Big Science investments. Achieving the critical mass of capabilities and resources required to support productive R&D in these fields demands the combined efforts of multiple institutions.

A third development is the changing demands of industrial innovation in which companies are moving away from a reliance on internal R&D and seeking broader sources for innovation across universities, other firms and federal research labs – a phenomenon referred to as “open innovation.” With open innovation the level of collaboration between universities and local industry becomes critical for advancing technology innovation in a specific area.

Appendix III

Federal Investments

The National Nanotechnology Initiative (NNI)

The National Nanotechnology Initiative is a multi-agency U.S. Government program aimed at accelerating the discovery, development, and deployment of nanoscale science, engineering and technology. The purpose of the initiative is to accelerate discovery and deployment of nanotechnology, expand knowledge, strengthen the economy, support national and homeland security and enhance the quality of life for all citizens.

The vision of the NNI is a future in which the ability to understand and control matter on the nanoscale leads to a revolution in technology and industry, highlighting areas of focus for Federal funding and how they relate to opportunities for NJ.

The goals are to maintain a world-class research and development program, to facilitate technology transfer, to develop educational resources and a skilled workforce supplied with an infrastructure and tools and to support the responsible development of nanotechnology.

The NNI budget grew from $464 million in 2001 to $1.05 billion in 2006. Eleven agencies have nano R&D budgets with most investment by National Science foundation, Department of Defense, Department of Energy, National Institutes of Health, and National Institute for Standards and Technology.

- Fundamental Nanoscale Phenomena and Processes ($234 million
- Nanomaterials ($228 million)
- Nanoscale Devices and Systems ($244 million)
- Instrumentation Research, Metrology, and Standards for Nanotechnology ($71 million)
- Nanomanufacturing ($47)
- Major Research Facilities and Instrumentation Acquisitions ($148 million)
- Societal Dimensions ($82 million)

Nanotechnology Centers-USA

Department of Energy Nanoscale Science User and R&D Centers

Five user facilities, called the Nanoscale Science Research Centers (NSRCs), are now under construction at national laboratories supported by the Department of Energy. The research facilities will focus on synthesis, processing, and fabrication of nanoscale materials. They will be co-located with existing user facilities to provide sophisticated characterization and analysis capabilities.

Specialized equipment and support staff will be available to the research community, where access will be determined by peer review of proposals. The listed below were conceived with broad input from university and industry user communities in order to define the scope of the equipment suite within each facility. They have been reviewed by external peers and by DOE's Basic Energy Sciences Advisory Committee.

National Institute of Standards and Technology (NIST) User Centers

Considered the most technically advanced research facility of its kind in the world, the new Advanced Measurement Laboratory (AML) dedicated on June 21, 2004 at the Commerce Department's National Institute of Standards and Technology (NIST) will support some of the world's most delicate experiments in nanotechnology and measurement at the atomic level. Commerce General Counsel and Deputy Secretary Designate Theodore W. Kassinger, Sen. Paul Sarbanes (D-Md.), Rep. Chris Van Hollen (D-Md.) and Dr. John H. Marburger III, Director of the White House Office of Science and Technology Policy, were among the participants in the formal opening ceremony at the NIST campus in Gaithersburg, Md.

NIST's new Advanced Measurement Laboratory (AML) is the most technically advanced research facility of its kind in the world. The $235 million, 49,843 square meter (536,507 square foot) laboratory features five separate wings – two of them buried 12 meters (39 feet) underground – with stringent environmental controls on air quality, temperature, vibration, and humidity. The new facility allows NIST to provide the sophisticated measurements and standards needed by U.S. industry and the scientific community for key 21st Century technologies such as nanotechnology, semiconductors, biotechnology, advanced materials, quantum computing and advanced manufacturing.

AML will support some of the world's most delicate experiments in nanotechnology and measurement at the atomic level. NIST research efforts planned for the new facility range from improved calibrations and measurement of fundamental quantities such as mass, length and electrical resistance to the development of quantum computing technology, nanoscale measurement tools, integrated microchip-level technologies for measuring individual biological molecules, and experiments in nanoscale chemistry.

The NIST Center for Neutron Research (NCNR) serves more than 1,700 scientists annually from industry, university, and government agencies. The NCNR is the only cold (i.e. low energy) neutron facility with comprehensive capability in the United States, providing tools essential to study the complex biological, polymeric and composite materials that are at the forefront of nanomaterials research.

Appendix IV

Competitive States, Their investments and Their strategies[2]

The following is an overview of some of the largest and most recent efforts by states other than New Jersey to support and advance nanotechnology. The summary includes information about research centers that these states have funded, initiatives they have undertaken, groups created to support nanotech, and reports prepared to examine the state of nanotechnology.

[2] Some of this information provided by State Science and Technology Institute

Arizona

Proposition 301, a voter initiative that passed in 2000, created a 0.6% sales tax increase for the purpose of enhancing education in Arizona. A portion of this 20-year initiative estimated at $1 billion provides for infrastructure enhancement at the three state universities in support of new economy jobs in Arizona. At **Arizona State University** (ASU), this $400 million state investment is focused on biotechnology, nanotechnology, information technology, and manufacturing science.

The initiative started in State Fiscal Year 2002. An **Arizona Biodesign Institute (AzBio)** was created in 2002 for the purpose of integrating new advances in biotechnology with that of nanotechnology and info-technology.

Combining the 301 initiative and ASU's commitment, the Arizona Biodesign Institute's total investment over the next five years is estimated to be $200 million ($140 million for two new buildings) and approaching $500 million over 10 years. Approximately $100 million of this is specifically coupled to nanotechnologies.

Additional investments in specific nanotechnology activities include Proposition 301 Materials/Nanotechnologies seed funding and equipment matches at approximately $0.5 million per year for shared user fabrication and characterization facilities at ASU (the Center for Solid State Electronics Research and the Center for Solid State Science, and upcoming seed investments in nanoelectronics and in sensing.

Arkansas

In 2005 during a visit to the Arkansas Research & Technology Park, U.S. Senator Mark Pryor (D-Ark.) announced formation of the **Arkansas Nanotech Alliance**. Pryor will chair the statewide consortium, bringing together "universities, federal agencies, and private sector partners to develop, launch and nurture nanotechnology initiatives."

He said that, in building an Arkansas nanotechnology community, some of the possibilities include:

- Establishing an information base, serving as a nanotechnology "clearing house" for regular news, funding updates and user services;
- Developing inter-institutional and inter-departmental research proposals to enhance federal funding and establish Arkansas as a major nanotechnology research center;
- Linking industry to nanotechnology research performed in the state, thereby enabling technology transfer, commercialization and economic development;
- Setting up open access research instrumentation centers for universities and industries; and,
- Outreach to the nanotechnology community by co-sponsoring scientific, educational and business meetings and conferences.

No other members of the Alliance were identified in Pryor's announcement and the Mar. 24 issue of the *Arkansas Democrat-Gazette* reported, "No federal funding is associated with the alliance - yet, Pryor said."

California

The **California Nanosystems Institute (CNSI)** is a research center run jointly by UCLA and UC Santa Barbara. CNSI was established in 2000 with $100 million from the State of California and an additional $250 million in federal research grants and industry funding. Its mission is to encourage university collaboration with industry and enable the rapid commercialization of discoveries in nanosystems.

Groups

Several promotion and networking groups are very active including:

- **NanoBioConvergence**
- **MIT-Stanford-Berkeley Nanotech Forum:** in Northern California.
- **NanoBioNexus** in San Diego.
- **Northern California Nanotechnology Initiative:** (regional)

Reports

A Blue Ribbon Task Force on Nanotechnology issued a report titled ***"Thinking Big About Thinking Small: An Action Agenda for California,"*** which urges California to act quickly or risk losing its nanotech edge to other states and nations. The report, commissioned by state controller Steve Westly, and Rep. Mike Honda, proposes actions including:

- Offer a "state income tax holiday" and sales-tax exemptions to nanotech investors and firms.
- Provide matching funds to nano-research enterprises.
- Seek federal funds to bankroll in-state nanotech initiatives.
- Make it easier to license and market California-developed nano-related products.
- Retrain mid-career professionals for the nanotech industry.
- Mandate science-math instruction in K-12 schools at a minimum of one hour a day.
- Monitor possible safety and environmental hazards of nanotechnologies.

A report from the **California Council on Science and Technology** titled ***"Nanoscience and Nanotechnology: Opportunities and Challenges in California 2004,"*** provides an analysis on numerous aspects of nanotechnology, including, among others, its economic impact; affected scientific disciplines; commercial best practices; workforce development issues and social and ethical issues. The report issues options for California's state officials and Congressional delegation to maintain and enhance California's nanotechnology competitiveness.

Connecticut

In July 2005, Governor M. Jodi Rell signed **Special Act 05–13** to help create higher education degree programs in nanotechnology. The law requires Connecticut's Commissioner of Higher Education, in consultation with the Office of Workforce Competitiveness, to review the inclusion of nanotechnology, molecular manufacturing and advanced and developing technologies at institutions of higher education. A report on their findings must be sent to the legislature by January 1, 2006.

Georgia

Georgia Tech is seeking state funding of $38 million toward a **new nanotechnology research center** when the Georgia Legislature goes into session in January 2006. Andrew Harris, director of Government Relations, indicated in a recent article in the alumni newsletter that the state Legislature has already allocated $7 million for planning and design of the facility, and that university officials are optimistic the governor will recommend funding the remainder of the state's $45 million share of the nanotechnology research center. He described the effort as an $80 million project, and said that Georgia Tech is going to raise $35 million privately.

Illinois

Illinois' AtomWorks coalition was one of the earliest and best known nanobusiness initiatives in the country. It was initiated by The Illinois Coalition, a private/public partnership including Illinois' Department of Commerce, the Chicago Mayor's Office and numerous corporate leaders. The organization serves as a clearinghouse of nanotechnology information, provides nanotechnology education, increases public awareness of nanotechnology's potential benefits, builds a community of interest for individuals and companies involved in nanotechnology, and develops networks of resources on behalf of those trying to commercialize nanotech innovations. It is currently creating an asset-inventory database of local infrastructure to support the nanotech community, establishing research and industry forums to address current issues, and building an online nanotechnology information hub. It plans to investigate the feasibility of a nanotechnology business park for the region; identify solutions to early-stage funding requirements of nanotech start-up companies; and attract national nanotechnology conferences to the region.

Illinois Research Centers

The Center for Nanoscale Materials (CNM) at Argonne National Laboratory is a joint partnership between the U.S. Department of Energy (DOE) and the State of Illinois, as part of DOE'S Nanoscale Science Research Center program. The state provided $36 million for the CNM building. The CNM serves as a user-based center, providing tools and infrastructure for nanoscience and nanotechnology research. The CNM's mission includes supporting basic research and the development of advanced instrumentation that will help generate new scientific insights and create new materials with novel properties.

The University of Illinois's Micro and Nanotechnology Laboratory (MNTL) for semiconductor, nanotechnology, and biotechnology research will grow due to an $18 million expansion project that paves the way for new bionanotechnology facilities and additional space for researchers. The money for this expansion is part of a state grant to the university that is funding construction of the Institute for Genomic Biology (IGB) and the new National Center for Supercomputing Applications (NCSA) facility. The MNTL expansion project, which is scheduled for completion in 2006, will add 45,000 sq ft. of space for offices, general-purpose laboratories, and a 3,000 sq. ft. bionanotechnology laboratory.

The website of the Illinois governor's office provides links to several Illinois research centers, including:

- The Beckman Institute for Advanced Science and Technology - University of Illinois
- Micro and Nanotechnology Laboratory - University of Illinois
- Institute for Nanotechnology - Northwestern University
- The James Franck Institute - University of Chicago
- Nano-CEMMS (Center for Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems), an NSF-sponsored center for nanoscale science and engineering

Maryland

The **Chesapeake Nanotech Initiative** (CNI) is a collaborative effort between Maryland, Virginia and the District of Columbia to accelerate the development of innovative products and entrepreneurial businesses in nanotechnology in the region. On May 31, 2005, Maryland Governor Robert L. Ehrlich, Jr., Virginia Governor Mark R. Warner and District of Columbia Mayor Anthony A. Williams agreed to sign a memorandum of agreement to form CNI. The Initiative is being launched by the Maryland Department of Business & Economic Development, Virginia 's Center for Innovative Technology, and the D.C. Office of the Deputy Mayor for Planning and Economic Development.

CNI will seek to raise funds from the State of Maryland, the Commonwealth of Virginia, the federal government and other sources.

Maryland Research Centers

Governor Ehrlich's **FY 2007 Science & Technology Budget** calls for $2.5 Million in new operating funds for a University System of Maryland Nanotechnology research initiative to encourage joint nano-biotechnology business development in Maryland and to develop nano-bio science in specific medical areas such as drug delivery, gene therapy, medical devices and coatings where nanotechnology has a direct application.

Massachusetts

Research Centers

In 2004, the University of Massachusetts Lowell Nanotechnology Manufacturing Center was awarded $5 million under the state's economic stimulus package and the John Adams Innovation Institute. The award went toward the creation of a statewide Center of

Excellence at the Nanomanufacturing Center. The matching grant came from the economic stimulus package, which created the $20 million University Investment Fund managed by the John Adams Innovation Institute, a division of the quasi-public economic development agency called the Massachusetts Technology Collaborative. The center is seen as a test facility for nanotechnology manufacturers that might serve to take small-scale breakthroughs at a billionth of a meter from the lab to the factory.

Reports

Although Massachusetts' universities may be at the fore of nanotechnology research and development (R&D), they must continue to win on research for the state to stay competitive for federal funds, suggests a recent report by the **Massachusetts Technology Collaborative** (MTC) and the **Nano Science and Technology Institute** (NSTI). Massachusetts is experiencing a surge in nanoscale technologies, according to *Nanotechnology In Massachusetts*. As of February 2004, close to 100 companies in the state were using or developing the technologies, half of which are within the healthcare and electronics industries. Massachusetts' venture capital community also has invested in companies using or developing nanotech. In 2003, these firms attracted more than $120 million in funding, second only to California's $480 million. The report cites nine Massachusetts universities involved in nanotech R&D, including **Harvard University,** the **Massachusetts Institute of Technology**, and the **University of Massachusetts campuses**. Additionally, two of the nine National Nanotechnology Initiative Centers and Networks of Excellence are located in the state.

For Massachusetts to remain competitive in nanotech R&D domestically and abroad, the report argues, the state's universities must continue producing the innovations that have made the state a leader.

Initiatives

The Massachusetts Nanotechnology Initiative is a project of the Massachusetts Technology Collaborative to foster research, new ventures and new job creation from the Commonwealth's base of nanoscale science and engineering**.** The website includes information on major nanotech research centers in Massachusetts and shared use resources for researchers and entrepreneurs.

Michigan

In 2002, the state helped launch the **Michigan Small Tech Association** as a promotion and networking group. The Michigan Small Tech Association (MISTA) is a community of companies, universities and individuals involved in or supporting micro and nanotechnology development in Michigan. Its goal is to promote acceleration of the industry through research, commercialization and the fostering of business relationships.

New York

New York has a series of programs to bolster university research and encourage the commercialization of the technology developed as a result of these programs. The state has funded a variety of nanotechnology projects through these programs; unfortunately, funding just for the nanotech projects is not available.

The Centers of Excellence Program, through Empire State Development, (the state's economic development agency), supports major upgrades of research facilities and other high technology and biotechnology capital projects, allowing colleges, universities and research institutions to secure research funding that will lead to new job creation. The program received $250 million in FY2003. One of five funded centers, the Center of Excellence in Nanoelectronics (http://www.albanynanotech.org/Programs/nanotech_centers.cfm), is focused on nanotechnology. The goal of the center, according to its website, "is to act as a world class center for pre-competitive and competitive technology deployment, quick turn-around prototyping, and workforce training and development using universal 200mm and 300mm wafer platforms. Its aim is to assemble the critical mass necessary for the creation of vertically and horizontally integrated industry-university consortia and public-private partnerships to convert long-term prospective innovations into real business opportunities and revenue-generating ventures within a technically aggressive and economically competitive technology development and deployment environment."

The Strategically Targeted Academic Research (STAR) Centers receive "financing for the design, acquisition, construction, reconstruction, rehabilitation or improvement of research and development facilities, including equipment." Of the eight STAR centers, one is focused on nanotechnology. The Nanoelectronics and Optoelectronics Research and Technology Center at the University at Albany and Rensselaer Polytechnic Institute "will serve as a fully integrated, long-term, visionary research and development resource that provides the science and technology base for future generations of integrated circuitry (IC)."

The Centers for Advanced Technology (CAT) program brings university and industry researchers together to develop new technologies and commercialize these developments. The program is designed to result in new products and processes, create new businesses, and ultimately, high-quality, high-value jobs. Of the 15 CATs, one is focused on nanotechnology, the Center for Advanced Technology in Nanomaterials and Nanoelectronics.

Additionally, in January 2006, Governor Pataki and legislative leaders announced that they would allocate $80 million to support a $435 million nanotechnology center to be built in Albany. The center, the Institute for Nanoelectronics Discovery and Exploration, (INDEX) will also include the Georgia Institute of Technology, Harvard University, the Massachusetts Institute of Technology, Purdue University, Rensselaer Polytechnic Institute and Yale University. INDEX will focus on the development of nanomaterial systems; atomic-scale fabrication technologies; predictive modeling protocols for devices, subsystems and systems; power dissipation management designs; and realistic architectural integration schemes for realizing novel magnetic and molecular quantum devices. In addition to the state support, INDEX also will receive direct funding from IBM.

North Carolina

In 1998 the major research universities, **Duke, UNC** and **NC State,** formed a joint research consortium called **NC Center for Nanoscale Materials.** NCCNM received primary funding from the Office of Naval Research Multidisciplinary University Research Initiative. From this consortium has arisen a number of small companies, which are now strong patent producers and magnets for nanoscience SBIR grants.

Ohio

Research Centers and Projects

Ohio's Third Frontier Initiative includes grants to support large-scale, world-class research and technology development platforms designed to accelerate the pace of commercialization through the **Wright Centers of Innovation**. Wright Centers are collaborations among higher education institutions, nonprofit research organizations, and Ohio companies. In FY 05, the state provided $22.5 million to the Ohio State University for the **Ohio Center for Multifunctional Nanomaterials and Devices**, which focuses on research, development and commercialization of nanocomposites, polymer-based biomedical devices, and polymer photonics.

The Biomedical Research and Commercialization Program has awarded $4 million since FY 02 for a Targeted Nanoparticles for Imaging Therapeutics Project at Case Western Reserve University. In addition, the state has awarded $5.3 million for three **Wright Projects** to support near-term commercialization projects requiring major capital acquisitions and improvements at Ohio higher education institutions and nonprofit research organizations.

Oklahoma

The **Oklahoma Nanotech Initiative (ONI)** is a project established in 2004, and coordinated by the **State Chamber of Oklahoma** and funded by the **Oklahoma Center for the Advancement of Science and Technology (OCAST)**, Oklahoma's state technology-based economic development agency.

ONI's main objectives include:

- Generating awareness of the emerging field of nanotechnology and educating Oklahomans about the potential impact of the industry on the state;
- Promoting Oklahoma and its resources as a valuable site for industry location; and
- Serving as an informational hub for the academic, financial, industrial and business communities.

Research Centers

The **University of Oklahoma's Center for Semiconductor Physics in Nanostructures (C-SPIN)** announced receipt of a six-year, $7.8 million National Science Foundation grant in 2005. In a collaborative effort with the **University of Arkansas**, the center conducts research in semiconductor nanodevices. Its focus is on developing novel nanoferroelectric materials that will increase the limits of optical resolution, advance handheld wireless devices and provide inexpensive memory that is fast, flexible, scalable, low-power and non-volatile, according to OU physics professor Matthew Johnson.

The NSF grant is supported by matching funds from OU and UA as well as the **Oklahoma State Regents for Higher Education** and the **Arkansas state government,** making the total funding close to $12 million. The OU/UA grant renews funding for C-SPIN, which previously received an award in 2000. Funding for C-SPIN also includes outreach to community high schools and grade schools, teachers and students, and national laboratories and businesses. C-SPIN provides teaching kits to area schools and laboratories as well as a number of museums in Oklahoma. One of the programs' goals is to educate society on the understanding of scientific methods, experiments, logic and research and implications for future technological and medical developments.

Oregon

State government authorized $21 million in 2003, with an additional $7 million in the governor's subsequent FY 05 biennial budget proposal to launch the **Oregon Nanoscience and Microtechnologies Institute (ONAMI)** targeted at fundamental and translational research for industrial applications, with significant support from **Hewlett-Packard** and other Oregon companies.

According to its website, The **Oregon Nanoscience and Microtechnologies Institute** is Oregon's first "Signature Research Center" for the purpose of growing research and commercialization to accelerate innovation-based economic development in Oregon and the Pacific Northwest. It is a collaboration involving Oregon's three public research universities (Oregon State University, Portland State University, University of Oregon); the Pacific Northwest National Laboratory; the state of Oregon; selected researchers from the Oregon Graduate Institute and the Oregon Health and Sciences University; and the "Silicon Forest" high technology industry cluster of Oregon and southwest Washington.

Pennsylvania

The **Nanotechnology Institute (NTI)** is a collaboration led by **Ben Franklin Technology Partners of Southeastern Pennsylvania, Drexel University** and **The University of Pennsylvania.** Its mission is to focus on the transfer and commercialization of nanotechnology discoveries and knowledge to stimulate economic growth through:

- **A Multi-Institutional/Inter-Disciplinary Research & Development** to facilitate the transfer and commercialization of discoveries and intellectual knowledge that support rapid application of nanotechnology to the life sciences sector and the creation of new enterprises around this technology.

- **A Comprehensive Approach** requiring the strategic alignment of six programmatic areas: Industry-Focused Research & Development, Entrepreneurial Business Development & Commercialization, Risk Capital, Workforce Development, Economic Research, and Community of Interest Networks.

$10.5 million in state funding was approved in September 2000. According to the NTI website, "the NTI research management's stress on outcomes has resulted in a disclosure rate per research dollar of seven times that of the individual institutions."

Texas

Texas has two organizations focused on promoting nanotechnology:

- Nanotechnology Foundation of Texas (NFT) describes itself as a research initiative funded by tax-deductible donations from individuals, corporations and foundations. The Foundation's purpose is to accelerate nanotechnology research in Texas by: providing funding to help current nanotechnology researchers expand their fields of investigation; sponsoring annual Nano Summit conferences to encourage collaboration among Texas nanotechnology researchers and to educate both Texans and those outside our state about the research being done in Texas in order to develop broader funding sources for Texas research; and, recruiting the most qualified graduate students and post doctoral researchers into the field of nanotechnology.

- Texas Nanotechnology Initiative states, "the best general description for TNI is as a state-wide industry trade group for nanotechnology. We will act to further the interests of our members through networking, education, and communication in order to promote the steady growth of a robust nanotechnology community in Texas." The organization "is dedicated to establishing Texas as a world leader in the discovery, development, and commercialization of nanotechnology. We have organized a consortium of Texas-based universities, industry leaders, investors, and government officials in order to foster communication, collaboration, and the sharing of resources to accelerate the realization of our goal."

Virginia

To develop and promote higher education research facilities and faculty in Virginia, Gov. Mark Warner proposed $218.8 million in his fiscal year 2006-08 biennial budget proposal for investment in university R&D. In response, state institutions of higher education have pledged to match the governor's proposal with a $299 million commitment.

The funding allows for the hiring of top researchers in the fields of biomedical science, biomaterials engineering, nanotechnology, and modeling and simulation, whose presence

will attract more grant-funded research to the Commonwealth, according to the governor's office. In addition to having economic benefits, the initiative also invests in the search for cures for cancer, diabetes, tuberculosis, Alzheimer's and Parkinson's diseases, the governor said.

The **Virginia Nanotechnology Initiative**, VNI, was initiated in 2002 (as INanoVA) with seed funding from CIT and has remained a program within CIT to work with Virginia's universities, federal laboratories, state agencies, and industrial partners to promote collaborative nanotechnology research, workforce development, technology transfer, and commercialization. CIT will play an active role in the Chesapeake Nanotechnology Initiative, but VNI will remain as a CIT program, continuing its role in advocacy, facilitating collaboration, and education.

Washington

The **Washington Nanotechnology Initiative** was created in 2004. The University of Washington had already received over $200 million in nanotechnology-related research awards. **Washington State University** and the **Pacific Northwest National Laboratories' Environmental Molecular Sciences Laboratory** were also among the earliest institutions nationally funded for pioneering research. In 2003, the **Washington Technology Center, Pacific Northwest National Laboratories, Avogadro Partners LLC**, and scientists from the state's research universities came together to assess how to best take advantage of the developing nanotechnology opportunity. Seed financing for a formal assessment came through an Economic Development Initiative (EDI) grant from the department of Housing and Urban Development (HUD) in FY 2004. The result was the Washington Nanotechnology Initiative (WNI). The WNI Action Agenda includes

- Establish new programs in each of Washington's key nano-affected industries
- Recruit high profile technologists to research and commercial organizations.
- Recruit a facilitator to develop a collaborative, interactive statewide nanotech community and assure recognition and visibility worldwide
- Create applied development centers focused on nanotechnology processes, fabrication, product development and support services.
- Develop and fund an integrated nanotechnology research agenda at Washington universities.
- Develop training programs to assure the state's workforce has the nanotechnology skills when needed.

Wisconsin

In 2004 Governor Jim Doyle called for creation of a new $375 million research institute - called the **Wisconsin Institute for Discovery** - at the **University of Wisconsin-Madison.** The Institute was proposed to include specialists in biochemistry, nanotechnology, computer engineering, and bioinformatics. The public-private Institute is intended to enable researchers to exercise their independence to convert their discoveries into commercial ventures that will create jobs. The Governor said it will be built and financed over 10 years, with support from state and private funds totaling $375 million. The first phase of the project will use approximately $50 million already set aside for BioStar IV.

Earlier in 2004, Governor Doyle signed legislation to fuel the process of turning ideas into jobs by leveraging over $250 million of venture capital to help start-up companies grow. When announcing the Institute for Discovery, the Governor also directed the Department of Commerce to make those resources available to companies that emerge from the Institute for Discovery.

The university has incorporated the proposed institute into its master plan issued in 2005.